NASA TECH BRIEF

Lewis Research Center

Investigations of Multiple Jets in a Crossflow

A multiple jet study was conducted to determine experimentally the penetration and mixing characteristics of multiple jets of ambient temperature air injected perpendicularly into a ducted mainstream of hot combustion gases. Although the interaction of subsonic jets injected normally into a subsonic mainstream flow has been the subject of numerous analytical and experimental studies, previous studies have been concerned only with single jet interaction.

Data on the penetration and mixing of jets in a crossflow have application to many problems of current interest, such as:

(1) Cooling of hot gas streams in numerous industrial and military devices;

(2) Film cooling of combustion chamber walls, turbine blades, and re-entry vehicle nose cones;

(3) The aerodynamics of STOL and VTOL aircraft; and

(4) The concentration and paths of pollutants downwind of industrial chimneys or downstream from discharge lines leading into rivers or streams.

The flow variables for this study were selected to make the experimental data relevant to the design of combustors for gas turbine engines. Through proper design of secondary air admission ports, the combustor length required to achieve uniform temperatures and mass flux profiles can be minimized and the decreased combustor length required for complete mixing will result in minimum residence time for production of nitrogen oxides.

The primary independent test variables were the orifice plate configurations (16 configurations were tested) and the ratios of jet-to-mainstream momentum flux. The orifice plates contained sharp-edged orifices ranging in diameter from 0.63 cm (0.25 in) to 2.54 cm (1.0 in), spaced from two to six orifice diameters apart. The momentum flux ratios were varied by changing the mainstream temperature and velocity. The mainstream flow fluid temperatures used were 450 K (350°F), 600 K (620°F), and 750 K (890°F); the mainstream velocity was varied from 15/m sec (50 ft/sec) to 40 m/sec (155 ft/sec).

A mixing parameter, E_T , derived from the experimental data, expresses the mixing effectiveness as a percent of the ideal energy exchanged between the cool jets and the hot mainstream. The correlation of E_T with the operating and design variables surveyed during the study are presented in graphical form (see Note 1). In addition to these E_T correlations, isometrics and contour plots of a non-dimensional temperature parameter are presented for a variety of test conditions and orifice geometries. These plots clearly illustrate the penetration and mixing characteristics of the jets under a variety of conditions.

Based on the evaluation of these data, the jet-to-mainstream momentum flux ratio is the most important operating variable influencing jet penetration and mixing. Neither the absolute momentum flux level of the two streams nor the jet-to-mainstream density ratio appear to significantly influence jet penetration or mixing, except for the density ratio contribution to the momentum flux ratio. At a given momentum flux level and distance from the injection plane, jet penetration and mixing increase with increasing orifice diameter, however, this is influenced strongly by orifice spacing. Closely spaced orifices tend to inhibit penetration of the jet into the mainstream. Under some conditions, double orifice rows or mixed orifice sizes in a single row yield better jet penetration and mixing compared to a single orifice row with the same total flow area. The multiple jet results of this study when compared to single jet data show that the interaction of adjacent jets influences the temperature and velocity centerline trajectories.

During the study, a jet-to-mainstream energy exchange parameter was defined which quantifies the mixing effectiveness over a range of test operating and design conditions. This parameter is very useful in correlating the combustor design variables and provides a single valued performance number for the overall efficiency of the mixing process at the plane of interest.

Notes:

1. Further information is available in the following report:
   NASA CR-121217 (N73-26286), Multiple Jet Study

(continued overleaf)

Copies may be obtained at cost from:
Aerospace Research Applications Center
Indiana University
400 East Seventh Street
Bloomington, Indiana 47401
Telephone: 812-337-7833
Reference: B75-10149

2. Specific technical questions may be directed to:
Technology Utilization Officer
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Patent Status:

NASA has decided not to apply for a patent.

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